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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A high temperature vacuum furnace for across-ply testing of carbon/carbon composites has been installed. This furnace has a double-walled water-jacketed vacuum chamber and is equipped with a 30 kVA variable output transformer, semi-automatic vacuum system, a digital temperature controller programmer, a two-color optical pyrometer, various thermocouples, and a digital data acquisition system. This furnace has been installed on an existing Model 1123 Instron and heating to 2200°C has been accomplished. Graphite toolings have been prepared and across-ply tensile testing to 1700°C have been conducted.

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EQUIPMENTS ACTUALLY ACQUIRED, INSTALLED, AND TESTED.

1. Model 1080 front loaded, graphite vacuum furnace. The furnace chamber is equipped with 3 inch travel bellows seal at the top with interchangeable push/pull rod connections at the bottom. This furnace has been installed on an existing Model 1123 Instron with 25 KN load capacity.

   Other features of the furnace are:

   a. The furnace chamber, the front door, and all the ports are constructed from type 304 stainless steel. All structural joints are heli-arc welds.

   b. The furnace has a double-walled, water-jacketed vacuum chamber. The chamber is the "full-front opening" type and is equipped with front door clamps.

   c. A sight port is located on the front door to sight the test specimen inside the furnace. An externally adjustable stainless steel shield is provided to protect the glass from vapor deposition.

   d. The furnace chamber has ports at the top and bottom through which the load train is inserted. Access ports are provided for thermocouple probes (control and work) and three flexible work thermocouples.

   e. Top and bottom loadings are through 2 inch diameter water-cooled rods made of 17-4 PH COND H-900 stainless steel with "1-8 UNC-2B, 1" deep treads on internal ends for connection to 2 inch diameter graphite push/pull rods. The top rod is sealed to the tank by welded stainless steel 3 inch travel bellows assembly. the bottom rod is o-ring sealed to the tank. The top and bottom water-cooled rod assemblies are interchangeable.

   f. The pumping port is located at the rear of the chamber.

   g. Power feed-throughs are internally water cooled and are through the front and rear of the furnace chamber.

   h. An inert gas kit is supplied consisting of one mechanical type vacuum gage, one relief valve and one manual shut off valve. This system provides for backfilling the vacuum chamber with inert gas, as well as conducting tests in an inert atmosphere.

   i. Couplings for an ion tube and a thermocouple tube are located on the furnace chamber.

   j. A covered solid bus from the front door terminals to connectors roughly in line with the door pivot is provided. The cables are attached to these connectors, thus minimizing the bending moment on the hinge as well as reducing the cable restraint to opening and closing the door. The cables to the front door are shortened

by running them from connections on the rear to the front door, further reducing the load on the door hinges.

The heat zone of the furnace has the following characteristics:

a. The heating element is a vertically mounted, split graphite resistance heating element. The front half is mounted on the front door and hinges with the door.

b. The insulation consists of graphite fiberboard surrounding the sides, top and bottom is split vertically to permit the front half to hinge with the front door and the rear half fastened to the furnace chamber. (Openings top and bottom for 2" diameter load train.)

c. A vertically split copper heater shell, with copper cooling coils brazed to the outside, is supplied. This is mounted in the furnace chamber and surrounds the shields on all sides. Both halves are water cooled. (Openings top and bottom for 2" diameter load train.)

d. The furnace uses the "clam-shell" design for heating element and heater shell so that the operator can install and remove test specimens easily as well as being able to check clearances prior to closing the furnace door. One-half of the heater shell, element and shield assembly will be mounted to the hinged front door. After a test has been completed, the operator can open the door, exposing the test specimen for easy removal. After a new specimen has been mounted between the load rods, clearances between the work and the element can be checked prior to closing the furnace door.

The utility requirements for the furnace are:

a. Electrical: 30 KVA, 480 volts, single phase, 60 hertz. Continuous and free of electrical noise or spikes. Single point entry at main circuit breaker.

b. Cooling water: 6 gmp at 70°F maximum (based on 35°F maximum rise). 50 psig minimum, 75 psig maximum. Clean and free of contamination and minerals.

c. Inert gas: Helium, argon as required for process or chamber release, 15 to 20 psig.

2. Vacuum system consisting of the following components:

a. The original two-stage, 18.2 CFM, Sargent Welch Model 8851 mechanical vacuum pump did not function properly. This pump was exchanged with an Alcatel Model 2033 with a capacity of 35 m^3/h. The exchange was through Thermal Technology with no extra cost charged to Wright State University. The performance of the substitute pump has been very satisfactory.

b. High vacuum pump: 1200 liters/second (air) oil diffusion pump Varian Model VHS-4 with integral cold cap, high vacuum valve,

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foreline valve, vacuum release valve (chamber), water-cooled cold trap and necessary manifolding.

c. The original thermocouple ionization guage, Varian Model 842 did not function properly and degassing of the ionization tube was not possible. This instrument was exchanged for a Varian Model 880 RS digital ionization thermocouple guage controller through Thermal Technology Inc. at no extra charge to Wright State University. Model 880 RS is for operation with one ionization and two thermocouple guages and covers the range from 2×10^{-10} to 9.9×10^{-2} torr. The unit is supplied with one NRC-563 hot filament guage tube and two NRC-531 thermocouple gauge tubes, complete with ionization guage tube. Unit is rack mounted with dimensions of 3 1/2" high, 19" wide and 11" deep.

d. Valve control panel - This valve control panel (graphic) provides a semi-automatic pumpdown method for control of the electro-pneumatically operated foreline, roughing high vacuum valves in the pumping system. Indicator lights provide the information as to the valve position. The switches are cascaded to prevent operation of valves out of the proper sequence.

e. Air pressure alarm - This system sounds an alarm when the air supple pressure drops below a set value. This unit was not included in the original proposal.

3. Furnace power supply consisting of the following components:

a. One variable output transformer which can deliver 25 KVA of single phase power.

b. One single phase power control fuse protection and current limiter.

c. Manually reset circuit breaker with automatic trip to protect furnace power transformer.

d. Control power transformer provides required voltage/s for all controls and instruments.

e. Miscellaneous items - Motor starters, circuit breakers, fuses, etc. as required.

f. Furnace power monitor and control: One voltmeter and one ammeter to monitor power to element.

g. Manually reset main circuit breaker installed on transformer enclosure (30 KVA).

h. Furnace control panel - This panel provides the necessary controls for the pumping system and heat zone contractor. It is also equipped with two meters; an ammeter and a voltmeter. This enables the operator to monitor the power being applied to the furnace.

i. Common ground power outlets for all equipment and instrumentations from the variable output transformer. This

feature was not included in the original proposal and is intended for minimizing electrical noise.

4. Temperature instrumentation consisting of the following components:

   a. One two-channel Honeywell Digital Controller Programmer DCP-700. This unit consists of two digital current proportioning three mode controllers—each complete with auto-manual station and accepting a control signal from temperature, thermocouple or millivolt source. Combined with both controllers is a two-channel digital programmer capable of storing up to 39 programs. Twelve external non-dedicated event switches are provided. Includes a selector switch for two sensors, (power transducer and optical pyrometer). This unit is a substitute for the older and more expensive model DCP-7700 which was originally requested. The DCP-700 has a digital indicator which measures the thermocouple output in ^{o}C and the outputs from the power transducer and the pyrometer in m V.

   b. Temperature sensor primary: Optical pyrometer, Ircon Modline R, dual wave length optical pyrometer with 1100^{o}C - 2500^{o}C range. Installed on standard front sight window with swing away bracket. The pyrometer is equipped with DC power supply and digital indicator for temperature in ^{o}C. This unit is a substitute for the less accurate and less expensive single-color Ircon pyrometer originally requested.

   c. Temperature sensor secondary: Type C, molybdenum sheathed, thermocouple assembly with seal gland, plug extension wire and alumina outer sleeve.

   d. Temperature instrument: A power transducer system that will monitor power in the furnace heating element and maintain a given setting for use with a recorder/controller.

5. Accessory equipment. Since the expected life of a graphite heating element is limited, a spare element has been obtained. The spare element was not requested in the original proposal, but was indicated in the interim status report.

   Items 1 through 5 were obtained from:

   Thermal Technology, Inc.
   90 Airport Road
   Concord, New Hampshire 03301
   Telephone: (603) 255-6605
   Attention: Mr. David E. Hemingway

   Total final cost of the above items, including transportation cost, is $90,690.81

6. Data acquisition and miscellaneous support instrumentations.

   In a letter to Dr. A.K. Amos, dated October 17, 1986, a request for the disposition of excess funds (actually $6,599.19, estimated as $7,443.00 at that time) for the purchase of some parts and instruments

was made. A notification indicating approval of this request was received on January 16, 1987. The following items, indicated in the interim report, have been purchased:

a. Zenith Model ZF158-42 P-C Compatible Mirco-Computer and ZVM-1240 12 inch high resolution monitor. Obtained from:

Zenith Data Systems
Hilltop Road
St. Joseph, MI 49085
Tel. (616) 982-3700

Total cost: $1,330.00

b. NEC P6-60 Printer, tractor feed, bidirectional No. 4202, obtained from:

Disk & Data
Eight North Market St.
Troy, OH 45373

Total cost: $555.00

c. Model 3021-21 Yokogawa Two Pen, multirange recorder obtained from:

Measurement Instrument East, Inc.
P.O. Box 163
Blairsville, PA 15717

Total cost: $1,415.50

d. IBM PC Data Acquisition Board and Control Adapter, purchased through:

Electronic Shop
Wright State University
Dayton, OH 45435
Tel. (513) 873-2598

Total cost: $175.00

e. Helium gas and control valve obtained from:
Central Stores
Wright State University
Dayton, OH 45435

Total cost: $62.15

f. One-eighth inch thick graphite felt used as radiation barrier inside the tubular puss rods. Obtained from:

Materials Unlimited
Baldwinville Road
Templeton, MA 01468

Total cost: $117.00

g. Data Acquisition Programming Support Software obtained from:

IBM Branch Office
33 W 1st. St.
Dayton, OH 45402

Total cost: $125.00

h. Two inch diameter T-6 graphite push/pull rods end pieces, manufacture by:

Micro-Mech Inc.
33 Newburyport Turnpike
P.O. Box 229
Ipswich, MA 01938

Total cost: $1,256.00

i. High Temperature Thermocouple 5% Rh/Tungsten 26% Rh with Tantalum and Molybdenum sheaths.

Total cost: $548.50

Type K Thermocouple and Thermocouple extension wire.

Total cost: $63.20

Doric Digital Temperature Indicator, Model 400A1D-OC-C.

Total cost: $440.00

All the above items were purchased from:

Schlemer Associates, Inc.
800 Compton Rd., Unit 35
Cincinnati, OH 45231
Tel. (513) 522-8340

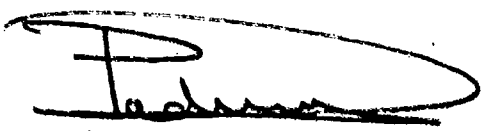
j. Hot Filament Variam 0563-K2466-304 Ionization Guage, obtained from:

Varian
121 Hartwell Ave.
Lexington, MA 02173

Total cost: $95.00

CONCISE SUMMARY OF RESEARCH PROJECTS

High temperature across-ply tension tests of carbon/carbon composites at temperatures up to 2000°C have been conducted. Substantial increase in across-ply strength with temperature has been observed. These activities are in part supported by a Research Challenge grant which is provided through Wright State University and is sponsored by the State of Ohio. Initial contacts with General Electric and NASA Langley for securing support for suture activities have been made.



P. Dedras

Professor

Mechanical Systems Engineering Department

Wright State University